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Development of LLNL Methodology for Nonnuclear Safety Bases

Charlotte M. van Warmerdam, David M. Pinkston

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Charlotte van Warmerdam
David Pinkston

Lawrence Livermore National Laboratory
925-423-0223/ 925-422-5180
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Abstract

The objective of this paper is to introduce the process and philosophies used to develop LLNL methodology for performing nonnuclear safety bases. Our former approach needed revision in order to implement the new Work Smart Standard (WSS), "Safety Basis Requirements for Nonnuclear Facilities at Lawrence Livermore National Laboratory Site Specific Standard" (UCRL-ID-150214), approved in 2003 and revised January, 2004.

This work relates directly to the following workshop theme: "Improvements in Chemical, Biological, and Non-nuclear Safety analysis."

A requirements document, Environmental Safety and Health Manual, Document 3.1 provides safety bases methodology “how-to” for LLNL personnel. This methodology document had to undergo a major revision, and essentially was completely re-written, since the nonnuclear requirements underwent a major change due to the new standard. The new methodology was based on a graded approach respective to risk level for each hazard type and facility classification. The development process included input from a cross-section of representatives of LLNL organizations at every step in the process. The initial methodology was tested in a pilot project that resulted in completed safety basis analyses and documentation for a major facility at LLNL. Feedback from the pilot was used to refine the methodology.

The new methodology promotes a graded approach to classifying and analyzing the 5 nonnuclear hazard types (chemical, explosive, radiological, industrial and biohazard) so that resources are focused more on the higher risk hazards and facilities, than the lower risk hazards and facilities. Also a lot was learned from the input gleaned from the LLNL representatives involved in the development process and from the pilot study.

The methodology document presents a streamlined and graded approach to analyze nonnuclear hazards. The process of involving "user-personnel" throughout the process, and testing the initial methodology in a pilot study improved and refined the final product.

Introduction

LLNL's former guidance manual, ES&H Manual, Document 3.1[1], for performing nonnuclear safety bases analyses required a major revision in order to implement the new Lawrence Livermore Work Smart Standard (WSS), "Safety Basis Requirements for Nonnuclear Facilities at Lawrence Livermore National Laboratory Site Specific Standard" (UCRL-ID-150214)[2]. This WSS includes a new conceptual approach to performing safety analysis on nonnuclear hazards. Guidance Document 3.1 establishes a methodology for implementation of the conceptual approach. The new methodology promotes a graded approach to classifying and analyzing all non-nuclear hazards so that resources are focused more on the higher risk hazards and facilities than those that are lower risk. An institutional committee was engaged to provide input on the draft ES&H Manual, Document 3.1, in order to develop a process workable in all the various LLNL directorates. Additionally, a pilot study was conducted to test and refine the draft methodology.

Methodology in a Nutshell

The new methodology covers 5 nonnuclear hazard types: chemical, explosive, radiological, industrial and biohazardous. Hazard classification is based on the potential for adverse health impacts to colocated workers and the public from an unmitigated release. There are 4 hazard classifications:

- Light Science & Industry (LSI)
- Low
- Moderate
- High

The general concept of the criteria, as described in Table 1, considers human health effects based upon a graded approach.

Table 1. Classification of Health Effects to Colocated Workers and the Public from Accidental Conditions.

Facility classification	Colocated worker impact	Public impact
LSI	No more than mild, transient adverse health effects or the perception of a clearly defined objectionable odor or sensation.	No appreciable risk of health effects.
Low hazard	No irreversible or other serious health effects or symptoms that could impair a person’s abilities to take protective action.	No more than mild, transient adverse health effects or the perception of a clearly defined objectionable odor or sensation.

Facility classification	Colocated worker impact	Public impact
Moderate hazard	Irreversible or other serious health effects or symptoms that could impair a person's abilities to take protective action.	No irreversible or other serious health effects or symptoms that could impair a person's abilities to take protective action.
High hazard	Potential for unmitigated release of hazards with impacts to colocated workers that are believed to include life-threatening health effects.	Irreversible or other serious health effects or symptoms that could impair a person's abilities to take protective action.

Facilities are classified according to the potential of their operations impacting colocated workers (at 100 meters away from release source) and the public (at the nearest site boundary), based on the effect of unmitigated releases of hazardous energy or materials. Criteria in Table 1 are based on the definitions for Temporary Emergency Exposure Limits (TEELs). While analysis was conducted to directly relate chemical exposure levels to these qualitative levels, facility classifications based on other hazards are more loosely aligned. Radiological and biological facility classifications are tied to existing WSS graded approaches (e.g. Radiological hazards: 40 CFR 302.4, "Designation Reportable Quantities and Notification Requirements", DOE-STD-1027; Biological hazards: *Biosafety in Microbiological and Biomedical Laboratories*, U.S Department of Health & Human Services, 1999).

For chemicals hazards the TEEL values at the site boundary were back calculated to allowable facility chemical inventories. EPI code calculations[3] determine the chemical inventory quantity (Q value) for each chemical that, if released, would result in exposures equal to the TEEL values at fixed distances from the release point. The Q values were developed by EPI code for LLNL Main-site facilities located 100, 200, 300, 600 meters from the nearest off-site fence-line (LLNL Site 300 facilities additionally include 1100 meters), using 50 % meteorological conditions. Facilities located in between these distances use the more conservative of the two distances adjoining their facility (e.g. a facility located 260 meters from the offsite fence-line uses the Q values within the 200 meter columns of the Q List).

For radiological hazards the sum-of the ratio calculation is used to determine radiological hazard classification:

- < 1 of RQ (40 CFR 302.4, Appendix B) = LSI
- > RQ and < Category 3 nuclear thresholds (DOE-STD-1027-92, Table A.1) = Low hazard
- > Cat 3 nuclear thresholds = Nuclear (and outside the scope of ES&H Manual, Document 3.1)

The radiological classification also includes Radiation Generating Devices (RGDs), which are mostly considered LSI, unless they meet the DOE 420.2A accelerator criteria.

Classification criteria for biological hazards are based on the highest Biosafety Level (BSL) within the facility per the *Biosafety in Microbiological and Biomedical Laboratories*, U.S Department of Health & Human Services, 1999 and the LLNL Institutional Biosafety Committee (IBC).

Explosive hazards classification is based on United Nations Organization (UNO) Hazard Class/Division, Quantity- Distance calculations per DOE M440.1-1, *DOE Explosives Safety Manual,* and other criteria as specified in Table 2.

For Industrial hazards, TEEL health-impact definitions are generally used as classification criteria.

Table 2. Classification Criteria.

Hazard Classification	Biohazard	Chemical	Radiological	Explosive	Industrial
Light Science & Industry	BSL 1 or 2 operations	Generally, small-scale chemical labs, dye laser labs, small quantity chemical storage, chemical inventories. ≤Q1 (colocated worker); ≤Q0 (public) as defined in the LLNL chemical Q List for classification.	Radiation generating devices not covered by DOE O 420.2A, radiological material sum of ratios <1 for RQs (See Table 7).	Powder-actuated tools, room inventories involving: • Secondary explosives ≤10 mg. • Primary explosives ≤1 mg. • Storage of ammunition classified as 1.4S per 5.4.3.4 of DOE-STD-1091-96.	Plumbing, carpentry, and machine shops using steel, aluminum, copper, plastic, wood, or other common materials; electronics shops; laser labs; and equipment design and testing labs.
Low hazard	BSL 3 operations	Facility inventory levels are ≤Q2 (colocated worker); ≤Q1 (public) as defined in the LLNL chemical Q List for classification.	Radiological material sum of ratios >1 for RQ but <Category 3 threshold (See Table 7), or qualified sealed sources >Category 3 threshold but exempt from inventory. Radiation Generating Devices covered by DOE O 420.2A, Accelerators.	The maximum credible event (used to meet the Level of Protection and QD requirements of the *DOE Explosives Safety Manual*) involves: • ≤10 grams of UNO Hazard Class 1.1, 1.2, 1.4 (except as stated for 1.4S for LSI facilities above), 1.5 or 1.6 explosives, or • ≤200 grams for UNO Hazard Class 1.3 explosives.	Industrial hazards that meet the following conditions for unmitigated releases: • No irreversible or other serious health effects or symptoms that could impair a colocated worker's ability to take protective action. • No more than mild, transient adverse health effects or the perception of a clearly defined objectionable odor or sensation to the public.

Hazard Classification	Biohazard	Chemical	Radiological	Explosive	Industrial
Moderate hazard	Not applicable	Facility inventory levels are ≤Q3 (colocated worker); ≤Q2 (public) as defined in the LLNL chemical Q List for classification.	There is no Moderate classification for radiological hazards. If inventory exceeds DOE-STD-1027 hazard Category 3 thresholds (i.e. sum of ratio ≥1), follow *ES&H Manual* Document 51.1.	• All activities or materials that are not allowed in Low facilities that: • Meet the QD requirements specified in DOE Manual 440.1-1. • Does not meet DOT requirements, when transporting explosive material in excess of LOW quantities on-site.	Industrial hazards that meet the following conditions for unmitigated releases: • No life-threatening health effects on colocated workers. • No irreversible or other serious health effects on the public or symptoms that could impair their abilities to take protective action.
High hazard	Not applicable	Facility inventory levels exceeding Q3 (colocated worker); Q2 (public) as defined in the LLNL chemical Q List for classification.	There is no High classification for radiological hazards. If inventory exceeds DOE-STD 1027 hazard Category 3 thresholds (i.e. sum of ratio ≥1), follow *ES&H Manual* Document 51.1.	Any activities or materials necessitating an exemption from the Quantity Distance (QD) specified in DOE Manual 440.1-1.	Hazard level exceeds that for Moderate.

The nonnuclear analysis process is shown in figure 1, Safety Analysis and Documentation Process. Figure 1 identifies the appropriate ES&H Manual, Document 3.1 section numbers for each process box. This helps the reader maneuver through the document. Additionally, this figure indicates the type and extent of documentation required for each hazard level. In general, the process steps are as follows:

- Define facility to be analyzed (building, complex of buildings, or segment of a building).
- Determine if the facility is an office.
- Perform a hazard screening of all facilities that are not offices. This screening process involves the identification of hazardous inventories and operations, and facility classification.
- Perform a hazard analysis of hazards that are classified above the LSI level. A safety analyst or individual with equivalent training performs this step. Unmitigated events are postulated and risk level is determined against the Analysis Level Matrix. This matrix is used to determine whether or not accident analysis is required. See figure 2.

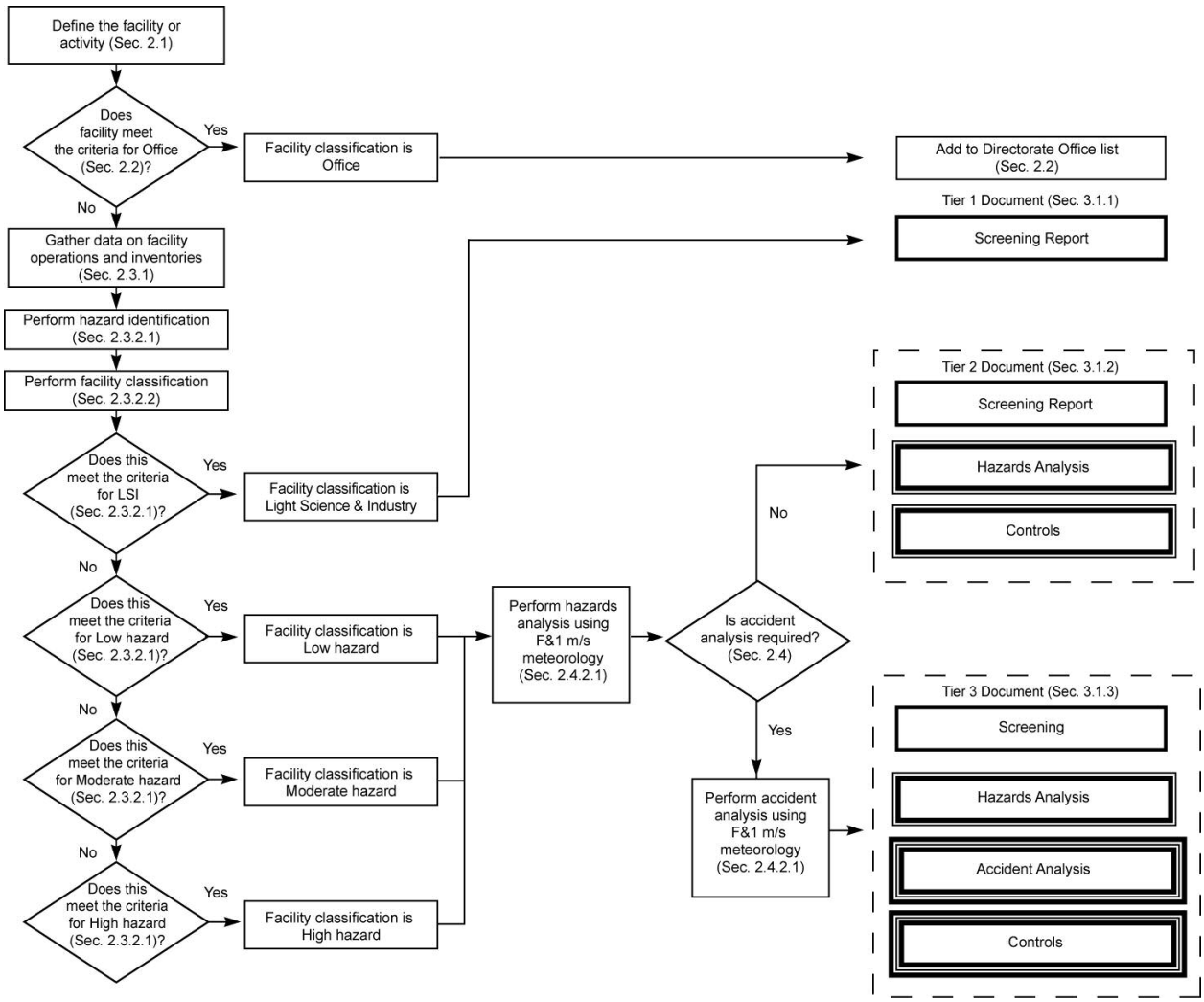

Figure 1 Safety Analysis and Documentation Process.

- Perform an accident analysis of all events identified in the Analysis Level Matrix as requiring accident analysis. In the accident analysis process, consequences and frequencies are estimated, and appropriate controls are identified. The resultant mitigated risks are compared against the Residual Risk Matrix, figure 3, to determine risk ranking, whether more controls are required in order to reduce risks, and the level of approval authority required. These controls are considered "credited controls". Operational Safety Requirements (OSRs) document, describe and maintain credited controls in the form of equipment and administrative controls. OSRs define the minimum conditions necessary to ensure safe operations with respect to colocated workers and the public at a distance removed from the immediate facility.

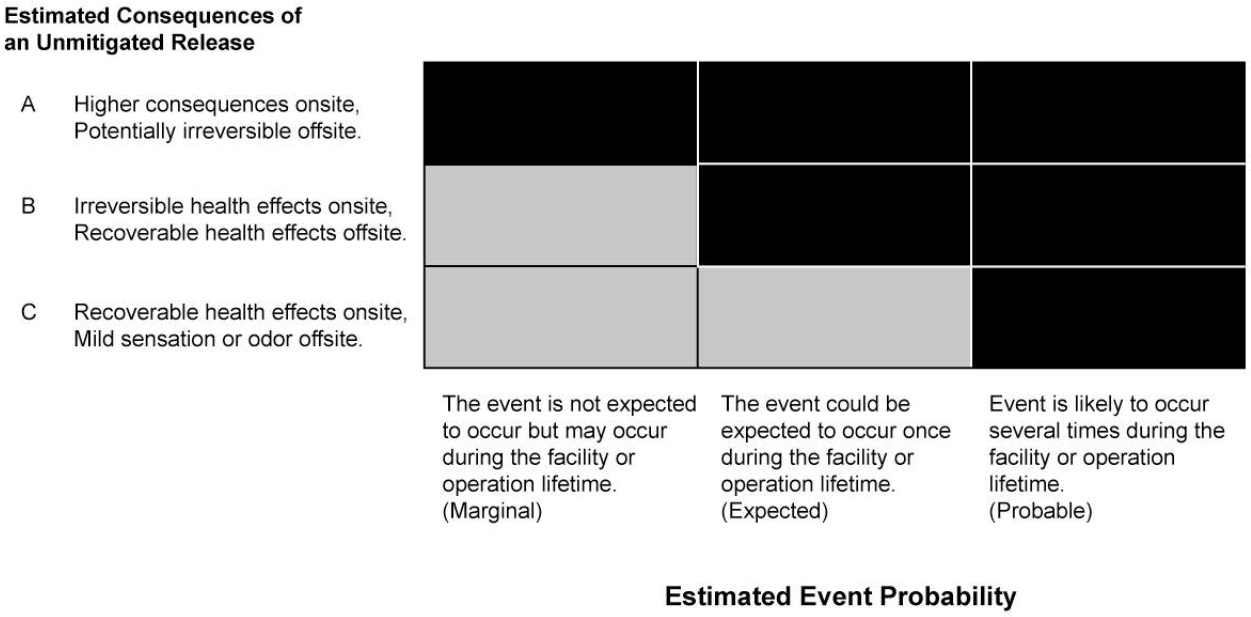

Figure 2 Analysis Level Matrix

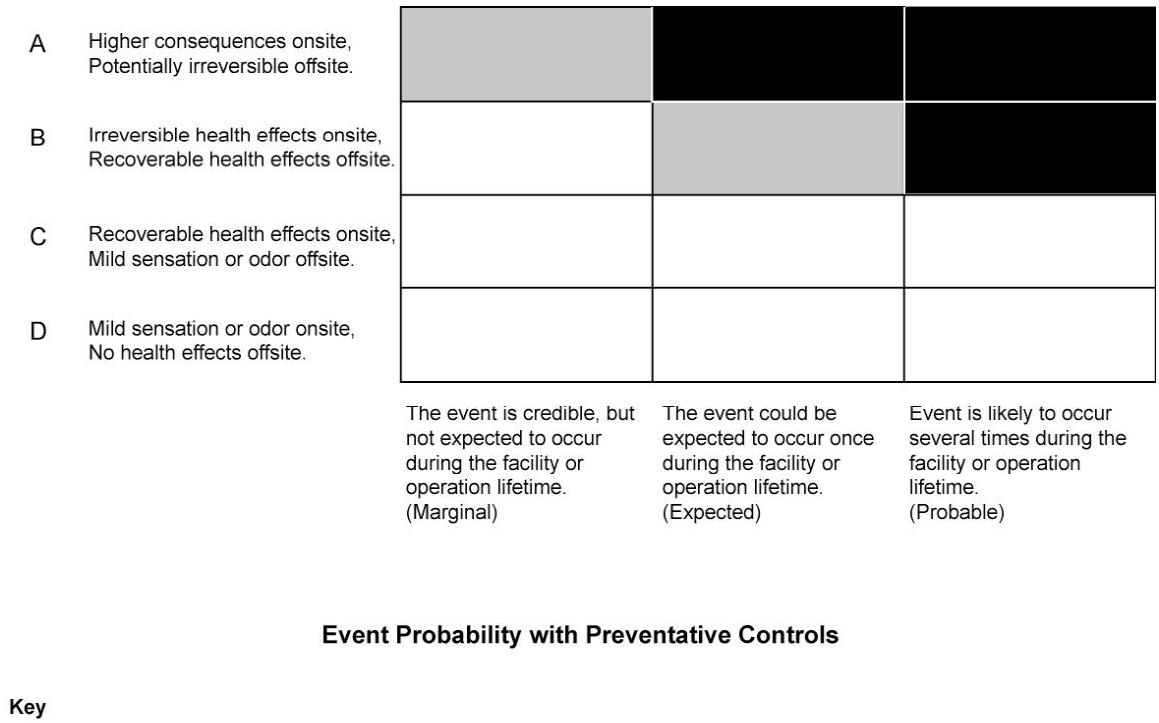

Figure 3 Residual Risk Matrix

Institutional Committee Involvement

An institutional committee, known as the Institutional Safety Committee, was involved in the development of the guidance document. They were involved in the very beginning of the development process. They represented a cross-section of Directorates across LLNL and it was their role to provide input regarding what form of implementation would work best within each of their respective Directorates. They critiqued even the very initial "stawman" conceptual papers that were developed as the methodology was being devised, over a 3-month period in which the first draft was developed. We met on a weekly basis to go over the conceptual approaches and to refine these as possible, to meet the needs and concerns of the respective committee members.

Pilot Study

Before attempting to finalize the draft Document 3.1 guidance, the institutional committee directed the performance of a pilot study. Of primary concern was the feasibility of the chemical approach, particularly with regard to the wide variety of chemicals for which limits were being set via the TEEL list. Accordingly, a large research laboratory was selected as the pilot case. While this facility used significant cumulative quantities of chemicals, the majority of its operations can be characterized as "laboratory scale" per 29 CFR 1910.1450, *Occupational Exposures to Hazardous Chemicals in Laboratories*. This allowed the pilot assessment to both (1) determine if the proposed methodology was too restrictive to accommodate the day-to-day reality of LLNL chemical operations, and (2) extrapolate that methodology to bulk chemical handling operations.

The majority of LLNL nonnuclear facilities present relatively low risk profiles and cannot reasonably expect DOE to provide large analytical support budgets. Therefore, any methodology must be cost effective. The pilot utilized four specific criteria:

1. Does the list of chemicals requiring detailed analysis become excessive?
2. Can any detailed analysis required be carried out in a relatively simple manner?
3. Can detailed analysis (using more restrictive meteorology) allow reasonable quantities for those chemicals above the LSI threshold?
4. Where credited controls are required, can they reasonably be extrapolated from current practice?

The first criterion was easily satisfied. The majority of the proposed TEEL-based Light Science & Industry (LSI) limits were quickly accepted by facility management as they were well above typical facility inventories. After making this determination, the algorithm used to generate those limits was reviewed again in conjunction with the local

DOE and deemed appropriate. This allowed the pilot effort to focus detailed evaluation on a small subset of six chemicals (acetyl chloride, sulfur dioxide, thionyl chloride, hydrochloric acid, chloroform, and bromine).

Criteria 2 through 4 were partially met. Practical analytical assumptions could yield acceptable results with reasonable controls; a "prove the negative" approach of the time sometimes associated with nuclear DSAs could not. Yet many of the hazards examined represent commonplace industrial or commercial activities carried out by the general public (e.g., receipt of shipping pallets, small-bottle acid storage, etc.) and governed by standards with historically acceptable levels of residual risk, whether explicitly or implicitly defined. Both LLNL and DOE concurred that either expending significant analytical resources on such issues or warping almost universal industrial handling practices solely to meet theoretical risk criteria would not be worthwhile. The latter case might, in fact, prove detrimental to safety.

As a result of the initial pilot, Document 3.1 was specifically revised in two ways. First, it established a "preponderance of the evidence" standard for analysis as opposed to requiring demonstration "beyond a reasonable doubt." That is, simple models and rule-based techniques were adopted. For example, spill evaporation calculations can use nominal temperatures and puddle depths as input to standard formulas; they need not "prove" no worse configuration could occur. Likewise, if an unmitigated release from a liquid spill inside a building is provided (i.e., ventilation to stack off and a leakpath factor of 1.0), the minimal wind speed associated with stagnant building conditions can be used to calculate evaporation rates. As an example of rule-based techniques, fires involving a number of small chemical containers do not require analysis. The base toxicity of the plume itself is considered to dominate over any number of small contributors. Only where a large accumulation of material can be pressurized or is held in place for accelerated boiling are fires considered. In such cases, full allowance for thermal lofting of plumes may be taken.

The second revision was made to the risk matrix. In the probable frequency range, special approval requirements were removed for 100-m exposures greater than TEEL-1 but less than TEEL-2 and site boundary exposures greater than TEEL-0 but less than TEEL-1. These criteria were deemed impractical for standard conservative meteorology (F stability and a wind speed of 1 m/sec), particularly for activities conducted outside. Maintaining special approval requirements for such activities could result in elevated approval being invoked for events as mundane as breaking a 1-liter bottle of standard industrial-grade acid on a loading dock. That is intuitively not a reasonable conclusion. The alternative of doing detailed frequency and human reliability analysis for such an event was considered a purely academic exercise, while the number of rule-based exceptions required for such events would become excessive. It is important when dealing with chemicals to avoid allowing arbitrarily defined risk matrices to preclude operational practices used everywhere else in the industrial world.

Using the revised Document 3.1, all four criteria defined were satisfied. The pilot facility was presented with a choice of (1) accepting lower limits on six chemicals to remain an LSI facility that did not require detailed analysis, or (2) implementing several operational safety controls based on current practice that would allow higher limits for several

chemicals. Management chose the first option, thereby implementing the most fundamental of safety controls, inventory reduction.

Conclusion

The finalized methodology is health impact based. The level of effort associated with analyses and documentation depend on the risk level: the higher the risk, the more extensive the analysis and documentation. There was also an emphasis on making the process as practical and user-friendly as possible. Therefore, the input and involvement of members of diverse directorates was sought. The draft methodology was then piloted in a large LLNL facility that contained all 5-hazard types, to test for practical applicability. The methodology was then refined as needed.

In total, the ES&H Manual, Document 3.1, went through four review and revision cycles. Members of the pilot effort used the first draft document, and offered useful comments and refinements based on their study. The original Institutional Safety Committee also provided comments on the first draft. The second draft was submitted to a larger institutional committee, the ES&H Working Group, of which most of the original committee participants were members. The third draft incorporated comments of the larger committee and that of their designees throughout all LLNL directorates. The fourth draft included final resolutions of comments previously made. The LLNL Deputy Director of Operations approved ES&H Manual, Document 3.1 on March 4, 2004.

References

1. Lawrence Livermore National Laboratory, UCRL-MA-133867, ES&H Manual, Document 3.1 "Nonnuclear Safety Basis Program", March, 2004

2. LLNL, UCRL-ID-150214, Rev. 2, "Safety Basis Requirements for Nonnuclear Facilities at Lawrence Livermore National Laboratory", January 2004.

3. Homann, S., *Emergency Prediction Information Code (EPI Code)*, Homann Associates.